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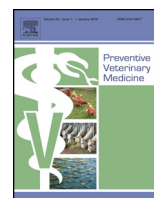
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Scenario planning: The future of the cattle and sheep industries in Scotland and their resiliency to disease

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ABSTRACT

In this paper, we present a description of foresighting activities undertaken by EPIC, Scotland's Centre of Expertise on Animal Disease Outbreaks, to investigate the future uncertainty of animal health security in the Scottish sheep and cattle sectors. Using scenario planning methodologies, we explored four plausible but provocative long-term futures which identify dynamics underpinning the resilience of these agricultural sectors to animal disease. These scenarios highlight a number of important drivers that influence disease resilience: industry demographics, the role of government support and regulation and the capacity for technological innovation to support the industry to meet local and global market demand. Participants in the scenario planning exercises proposed creative, robust strategies that policy makers could consider implementing now to enhance disease control and industry resilience in multiple, uncertain futures. Using these participant-led strategies as a starting point, we offer ten key questions for policy makers and stakeholders to provoke further discussion about improving resiliency and disease preparedness. We conclude with a brief discussion of the value of scenario planning, not only for the development of futures which will inform disease contingency plans and improve industry resilience, but as a mechanism for dialogue and information sharing between stakeholders and government.

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1. Introduction

Animal disease preparedness has been at the top of the UK animal health agenda for government policymakers, stakeholders and the public after a number of recent animal disease outbreaks (e.g. Bovine Spongiform Encephalopathy (BSE) in the 1990s, Foot and Mouth Disease (FMD) outbreaks in 2001 and 2007). In particular, the 2001 FMD epidemic led to increases in the complexity of thinking about mitigating animal health and food security risks posed by exotic animal diseases. It was the “single largest FMD epidemic the world had ever experienced” and one of the “most

serious animal disease epidemics in the United Kingdom in modern times” (Rossides (2002) at page 831). In 2001, the long-term impact of the outbreak on the farming industry was not certain, but it was immediately clear that the consequences of the disease were not confined just to the livestock sector. The lack of preparedness by the British government, the need for military intervention and the economic effects on tourism and business activities had an important impact on society and on public confidence in science and scientists to produce trustworthy evidence for decisions in animal health policy (Boden et al., 2014). More fundamentally, the outbreak called into question the “role and public expectations of agriculture”, its strengths and weaknesses, and its future, given its inter-dependent links with the wider rural economy (Rossides (2002) at page 831). Since then, there have been other smaller scale exotic animal disease outbreaks in the UK (e.g. FMD in 2007 (Anderson 2008), Bluetongue virus (Landeg, 2007)) and the emergence of novel pathogens such as Schmallenberg virus (Beer et al.,

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2013) which have maintained the risks associated with animal disease at the forefront of societal thinking.

Subsequently there has been a desire by both scientists and policy-makers to characterize, quantify and prioritise the risks that animal diseases pose for the near future. This aspiration has resulted in the generation of a portfolio of numerous probabilistic forecasting models and risk assessments (for example: Roberts et al., 2011; Del Rio Vilas et al., 2013). These tools have been refined as scientific knowledge and technology have evolved over time. However, these models typically rely on a single version of the future (Hopkins and Zappata, 2007), ideally parameterised with data from the present or recent past. Although they may be able to quantify uncertainty around the probability that risks will occur, their usefulness is contingent on knowing and identifying these risks in advance. Epidemiological, statistical or probabilistic models cannot take into account the uncertainty associated with ‘unknown unknowns’ (i.e. radical uncertainties (Nussbaum, 2011)) or the uncertainties and reflexivity inherent in the diverse range of factors (such as climate change, consumer preferences, politics, land use and commerce) which interact to compound risks over very long time periods (20–30 years).

The need to include uncertainty in the assessment of risks is the reason that the “contemporary logic” (Lentzos and Rose (2009) at page 236) of animal health security has a focus on resilience, a concept which goes beyond objective contingency planning and preparedness approaches. Resilience is the capacity to “better anticipate and tolerate disturbances in the world without collapse, to withstand shocks and rebuild as necessary” (Lentzos and Rose (2009) at page 243). It encompasses broad approaches to “thinking about change and societal responses to it” (Leach et al. (2010) at page 370) and thus is contingent on the context and perspectives of those whose resilience is at stake (Leach et al., 2010). Improving and evaluating resilience requires a paradigm shift in the way we rationally and scientifically think about multiple, uncertain futures. It is arguable that there is an increasing role for the incorporation of futures thinking in animal health using methodologies like scenario planning in order to:

- explore the joint impact of multiple but equivalent uncertainties,
- include elements which are difficult to model quantitatively (e.g. value shifts, or new regulations),
- challenge standard assumptions and highlight blind spots or ideas that may otherwise be ignored by decision makers,
- capture rich data on a range of possible and plausible futures which can be condensed into narratives which are easy to grasp and communicate to stakeholders.

(adapted from Schoemaker (1995) at pages 26–27).

In this study, we present a description of the scenario planning work undertaken by EPIC, Scotland’s Centre of Expertise on Animal Disease Outbreaks, to investigate the future uncertainty of animal health security in the Scottish sheep and cattle sectors. We explore four future scenarios to make inferences about the resilience of these agricultural sectors to animal disease and offer ten key questions for policy makers and stakeholders to provoke further discussion about improving resiliency and disease preparedness. We conclude with a brief discussion of the value of scenario planning, as a mechanism for dialogue and information sharing between stakeholders and government.

2. Materials and methods

Scenario planning is a tool to facilitate qualitative, structured, medium to long-range strategic thinking about plausible and internally consistent futures. A number of different definitions and

methodologies for scenario planning have been identified and described in the literature (Kahn and Wiener, 1967; Schoemaker, 1991, 1995; Bunn and Salo, 1993; Ratcliffe, 1999; Chermack et al., 2001). The EPIC workshops for Scottish cattle and sheep sectors included elements of the scenario planning process described by Schoemaker (1995). This process includes: defining the scope of the question, identification of stakeholders, identification of basic trends, identification of key uncertainties, construction of initial scenario themes, checking for internal consistency and plausibility of narratives through a back-casting exercise, development of preliminary (learning) scenario narratives and use of scenario narratives as decision tools (Schoemaker, 1995). The research approach was given ethical approval by the Animal Health and Welfare Division of Scottish Government and a James Hutton Institute ethics committee. Data were collected during four workshops: two held in 2013 (April and May, 2013) and two held in 2014 (February, 2014).

The scope of this study was encapsulated in the following focal question (that was addressed in separate cattle and sheep workshops): “What will the Scottish livestock industry look like in 2040 and how resilient will it be to livestock disease?” Participants in each workshop formed interdisciplinary teams including stakeholders from Scottish cattle or sheep sectors, farming, wildlife/forestry, Centres of Expertise on water and climate change, economists, agricultural and social scientists, veterinarians, epidemiologists, EPIC scientists and Scottish Government policy staff. Participants were given the role of scenario planners, tasked with engaging in strategic thinking through a series of carefully crafted exercises that resulted in the creation of four scenarios describing the situation in 2040 for each sector. Basic trends were considered through the creation of a historical timeline (Fig. 1). This process involved the identification and verification of important past events and influences on the development of the present day cattle and sheep industries. The timeline included directly relevant events but also other exogenous factors which may have had an indirect impact on sheep and cattle sectors (for example: climate change, increasing drug resistance, afforestation, the economy, the influence of energy prices and the cost and availability of labour). The historical timelines for the cattle and sheep sectors were created outwith the exercise, informed by expert opinion, with some further developments to the sheep timeline by participants at the workshop. In both cases, the historical timeline was a useful reference to ‘ground-truth’ (Lempert et al., 2003) the list of important driving influences for the future (from the categories of population, consumer and animal demographics, technology, economy, society, environment and politics). The list of drivers in this study was compiled in advance of each workshop and discussed in detail and refined with participants. A summary of the drivers is presented in Table 1. Key uncertainties were identified through a participant-driven process which resulted in a ranking of drivers separately for relative impact and uncertainty (i.e. the larger the range of plausible outcomes of a driver, the greater the uncertainty). High impact, high uncertainty drivers were clustered into themes, and hereafter referred to as critical uncertainties. Critical uncertainties were expressed as axes, representing a continuum of possibilities between two extreme endpoints. The axes for the cattle and sheep scenario planning events are presented together in Fig. 2. Two critical uncertainties were selected independently by participants at both workshops: (1) prioritisation of the industry by government and (2) technological innovation. The third parameter varied between the sectors, with government regulation chosen in the cattle sector workshops and market demand in the sheep sector workshops.

In each sector, four initial scenario themes were chosen in collaboration with workshop participants by selecting a combination of different positions on each of the three axes. Scenario development was guided by plausibility, internal consistency, diversity and poten-

Historical Timeline

1940 - 2014

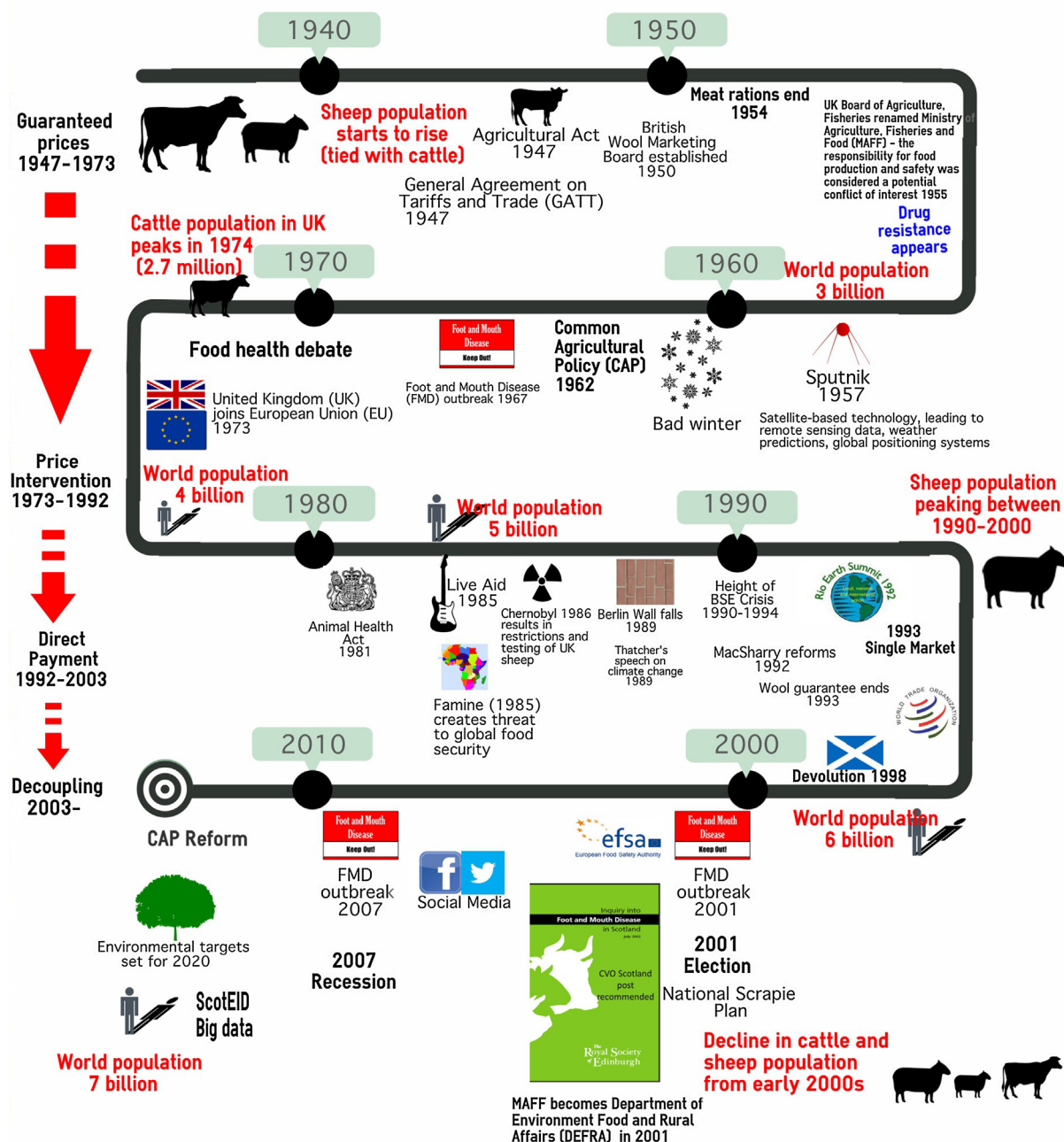


Fig. 1. Influential drivers which have shaped the Scottish sheep industry. This includes a number of seemingly unrelated, but relevant drivers which illustrate the interconnected and interdependent nature of risk factors that can cause shocks to the system in unlikely ways. For example, Sputnik, the first satellite, is important in this timeline because it represents the start of satellite-based technology, leading to remote sensing data, weather predictions, global positioning systems. The Chernobyl disaster had substantial impact on UK sheep farmers through restrictions and testing, so illustrates the potential for global phenomena or disasters to impact on Scottish farmers. Live Aid, and its attempts to raise awareness of famine, illustrates issues of global food security.

Table 1
Drivers of change for the Scottish sheep and cattle industries. These drivers were identified prior to workshops but were 'ground-truthed' through discussions of a historical timeline of the industry. These drivers were subsequently prioritised for their *impact and uncertainty*.

Population/ demographics	Technology	Economy	Society	Environment	Politics
World population UK population	Biotechnology Information technology	Globalisation Localisation	Education Health and wellbeing Food values	Climate change and disease Climate change and agriculture	Scottish independence Influence of EU
Farming demographics	Digital age	Trans-boundary risk Developments in retail sector Economic prosperity Global trade Marketing Food security Energy costs	Animal welfare values	Future land use	Governance
Consumer demographics and preferences	Changing systems of production Influence of renewables Alternative protein sources Veterinary science Research and development				National policy Fiscal policy

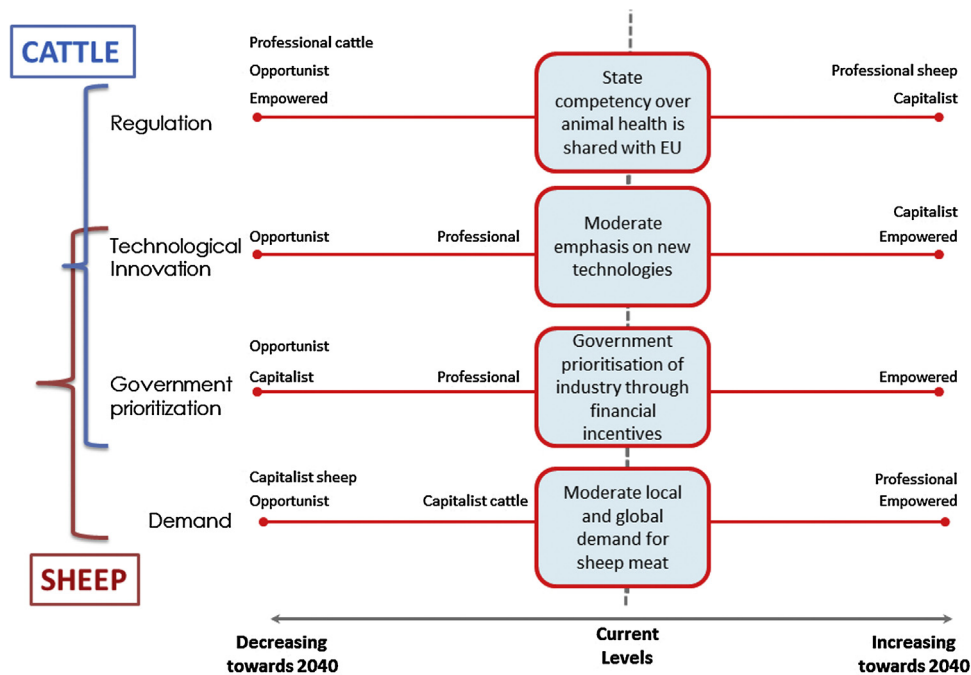


Fig. 2. Scenario themes (or axes) created from critical uncertainties. The names of the new scenarios (which incorporate features of both cattle and sheep sectors) have been added to these axes to illustrate how axes are used to construct scenarios from critical uncertainties. Government prioritisation and technological innovation were independently recognised as critical uncertainties by both sectors. The sheep workshop participants prioritised market demand, while cattle participants prioritised government regulation as the third critical uncertainty.

tial for stimulating discussion about each future. A *preliminary scenario narrative* for each future was characterised by participants followed by a 'back-casting' exercise to describe specific events which would unfold in a consistent and plausible manner along the time-line between 2014 and 2040. The back-casting exercise was an opportunity to consider the effect of drivers that were not eligible to define the axes but were nevertheless held to be important drivers of change by the participants. For example, high impact, low uncertainty drivers, such as globalisation and population growth are important features of all scenarios which needed to be considered during this process. The emphasis of the back-casting exercise was on small group ($n \sim 8$) participation to consider the inter-play between different driving forces. The back-casting process was important not only for collaboration and building of multi-disciplinary relationships within groups but also to attempt to establish 'buy-in' or commitment to the development of a plausible future.

Preliminary scenario narratives were developed by participants and refined over the course of the workshop and subsequently used to prompt participants to consider potential challenges and oppor-

tunities in each future. Inferences about resilience presented later in this paper were based on the degree to which these opportunities and challenges promoted or inhibited industry capacity to: detect disease, assess risks, respond to a disease emergency and recover from such an event. It is worthwhile to note that effective coordination of activities and communication between the many actors involved in a disease outbreak response is critical to all four stages of resilience. As these futures are not predictive, it is also important to bear in mind that the inferences about resilience, although plausible, are not probabilistic in nature. The future is likely to contain elements of each of the scenarios, in a combination that cannot be forecast.

Finally, the preliminary scenario narratives were used by participants as *decision tools* to stimulate imaginative discussion within the workshops about strategies which could be implemented in 2014 to improve resilience by 2040. The robustness of these strategies was then compared across all four scenarios in each sector.

After the conclusion of the workshops, we conducted a cross-scenario analysis of the 8 preliminary scenarios (c1–4, s1–4 in Table 2). The common characteristic from the preliminary scenarios

Table 2

A cross-scenario comparison of scenario characteristics.

Characteristics	Cattle scenarios				Sheep scenarios			
Original workshop scenario	C1	C2	C3	C4	S1	S2	S3	S4
Sector approach	Professional	Empowered	Capitalist	Opportunist	Professional	Empowered	Capitalist	Opportunist
Farmer Demographic	Fragmented industry; commercial and hobby; Loss of farming heritage	Strong & efficient commercial industry	Fragmented industry; commercial and hobby; Loss of farming heritage	Anyone can farm	Fragmented industry; commercial and hobby; Loss of farming heritage	Strong & efficient commercial industry	Fragmented industry; commercial and hobby; Loss of farming heritage	Anyone can farm
Farmer succession plans	Few farmers have succession plans (ageing farmers a problem)	New entrants	Unlikely	New entrants	Few farmers have succession plans (Ageing farmers a problem)	New entrants	Unlikely	New entrants
Hobby farmers	Increase due to 'city refugees'	Commercial is more incentivised, but hobby farms exist	Overall decrease due to regulation	Form a higher proportion of all farms	Increase but not significant	Commercial is more incentivised, but hobby farms exist	Overall decrease due to regulation	Form a higher proportion of all farms
Education initiatives	Yes	Yes	Yes	No	No	Yes	Yes	No
Animal numbers	Moderate	High	Low	Low	Moderate	High	Low number of ewes	Low
Extensive/intensive	Mixed	Extensive (prohibition on zero-grazing)	Intensive	Extensive	Mixed	Mixed	Semi-intensive (increased indoor rearing)	Extensive
Stocking density (concentration)	High (for agri-businesses)	High	High (for agri-businesses)	Low	High (for agri-businesses)	High	High (on lowlands)	Low
Regulations	High	Low (at EU level)	High (at EU level)	Low	Low	Low (at EU level)	High	Low
Government support	Moderate	High	Low	Low	Low	High	Low	Low
Technology	Moderate uptake and innovation	Innovation	Innovation	Stagnation	Low-moderate uptake of existing technology	Innovation	Innovation	Stagnation
State veterinary infrastructure	Strong	Strong	Weak	Weak	Weak	Strong	Weak	Weak
In-house health management	Yes (agribusiness)	Yes	Yes	No	Yes (agribusiness)	Yes	Yes (focus on genetic improvements)	No
Role of environment	Not a priority	Secondary to farming	A priority	Not a priority	Emerging priority-changing land use	Secondary to farming	Emerging priority-changing land use	Emerging priority-changing land use

In the original cattle and sheep workshops the participants created names for each scenario. These names were retrospectively considered to be value-laden so we have not used them in the titles of this table. However, in order to reference these against the online report, we present the original scenario names here: C1, Status Quo; C2, In Clover; C3, Quality Street; C4, Wild West; S1, Opportunity Knocks; S2, Three Bags Full; S3, Sheepishly Smart; S4, Silence of the Lambs.

Box 1: Scenario characteristics.

Farmer demographics
 Farmer succession plans
 Hobby or commercial
 Use of education initiatives
 Extensive versus intensive production systems
 Animal population demographics
 Stocking density
 Influence of government regulation
 Influence of government support/prioritisation of the industry
 Degree of technological innovation or stagnation
 State veterinary infrastructure
 Use of in-house health management
 Role of the environment

in cattle and sheep were then used to create four final future scenarios. We then considered each of the strategies put forward by participants in the workshops, in the context of these four scenarios (and their vulnerability to disease) to create a list of questions for policy-makers and a summary of mechanisms to improve resilience in the future.

3. Results: Resiliency in a variety of futures

The EPIC scenario planning workshops resulted in the development of eight individual future preliminary scenarios (four for each sector, c1–4, s1–4 in [Tables 2 and 3](#)). A descriptive narrative of each preliminary scenario is presented in the official cattle and sheep reports available online ([EPIC, 2014a,b](#)). All preliminary scenario narratives were translated into infographics which were used to prompt discussions about convergent, congruous and competing values and interests with livestock industry and other indirect stakeholders (including water users, wildlife, and land-owners) outwith the workshops. These infographics are presented in both reports.

A cross-scenario comparison of preliminary scenarios (c1–4, s1–4) highlighted important similarities and differences within and between livestock sectors (see [Box 1](#) for a summary of these characteristics and [Table 2](#)). The characteristics which underpin resilience in each preliminary scenario with respect to disease, animal welfare and trade are described in [Table 3](#). Whilst there are inherent differences between the cattle and sheep sectors (for example, the lower relative value of individual sheep compared to cows means the sheep sector is more vulnerable to external influences such as market conditions and the buoyancy of other livestock sectors), common themes emerged from the narratives, which could be assessed across both sectors. The common characteristics from the preliminary scenarios in cattle and sheep were subsequently consolidated to develop four final scenarios which, as convenient shorthand, were named by the research team: 'Professional', 'Empowered', 'Capitalist', and 'Opportunist' ([Tables 2 and 3](#)).

3.1. Professional

The 'Professional' scenario is defined by a combination of moderate government prioritisation and moderate technological innovation, in association with different levels of government regulation (high in cattle, low in sheep) and reasonably strong local and global market demands (sheep) ([Fig. 2](#)). The risk of disease incursion is highly uncertain and dependent on the livestock sector (and support from the government), and the degree to which farmers are knowledgeable and proactive about disease surveillance and management.

3.1.1. Industry structure

In this future, the industry has not grown in size since 2014, but has become increasingly fragmented. There will have been a loss of farming heritage as 'traditional farmers' (i.e. those with historical farming backgrounds) are replaced by larger (but fewer) agri-businesses and a growing enclave of hobby farmers. The loss of heritage in this scenario is largely due to a combination of unsustainable competition from agri-businesses, a lack of foresight and succession planning, despite early industry awareness of the ageing farmer demographic, and, for the cattle industry, increased burdens of compliance with an increasing degree of regulation

3.1.2. Resilience

If technological innovation and education are prioritised in 2014, professional farmers, in particular, will be well placed in 2040 to establish in-house management of animal health and disease detection, regardless of whether government support is strong or weak. Continued prioritisation of the industry by government would mean that disease control and eradication programmes will be government-led and well supported through a robust veterinary infrastructure. The latter would support continued professional development to improve animal disease contingency plans. However, if government support weakens (i.e. in the sheep sector) there may be insufficient resource to preserve adequate outbreak preparedness and control measures. Professional farmers will be compliant with new government-led interventions to improve biosecurity, but compliance in the hobby sector will be uncertain. Horizon scanning and disease prioritisation tools, based on transparent scientific evidence will continue to assist government-led prioritisation of resources for important disease risks. As a result, the overall likelihood of disease incursion and establishment will be low. However, if disease incursion were to occur, there is a risk that spread may be rapid and on a large scale if agribusinesses were to be affected. Hobby farmers will play an important role in the delay of disease detection. If government support were to diminish in the future, resulting in fewer regulations and financial support and a leaner state veterinary service, this will reduce overall resilience. This is particularly the case if there is little technological innovation or uptake and no training or education initiatives to ensure that industry members are well prepared to lead disease control (see [Table 2](#) and [Table S1](#)). If technological research and development is not prioritised, some farmers may look online or to 'black markets' (i.e. illegal traders) to access new pharmaceuticals which have been shown to be effective elsewhere.

3.1.3. Mechanisms to improve resilience ([Table 4](#))

A fragmented, diverse industry can remain strong provided there is sufficient solidarity and cooperation between big and small farm enterprises to control disease in these sectors. Present-day (2014) initiatives are important to strengthen the state veterinary infrastructure and improve education for new entrant farmers. These include training on biosecurity measures such as in-house diagnostics, closed herds, and risk management. Pharmaceutical legislative reform may need to be considered in the near future in order to ensure harmonised international standards for drug licensing across all markets and fast, equitable access to new drugs

3.2. Empowered

In the 'Empowered' future, there is support for technological innovation, government prioritisation of the sector, low regulations (at European Union (EU) level) and strong local and global demand for sheep and cattle products ([Fig. 2](#)). The likelihood of

Table 3

Cross-scenario comparison of scenario resilience to disease.

Characteristics	Cattle scenarios				Sheep scenarios			
Original workshop scenario	C1	C2	C3	C4	S1	S2	S3	S4
Sector approach	Professional	Empowered	Capitalist	Opportunist	Professional	Empowered	Capitalist	Opportunist
Animal welfare	Increased health initiatives in agribusinesses; variable hobby sector	High	Increased health, but intensive stocking raises questions	Low	Decreased-professional farmers are 'sitting back and making money'	High	Increased health, but intensive stocking raises questions	Low
Likelihood of any disease incursion	Low (some uncertainty due to hobby sector behaviour)	Low	Low (with some uncertainty due to possibility of emergent black markets or illegal trade)	High	High due to poor funding for surveillance	Low due to education & biosecurity	Low due to reduction in imports	High risk due to low surveillance
Likelihood of endemic disease	Low in agribusinesses which use technology	Low due to new technologies/ breed for health	Low due to new technologies	High	Moderate – high depending on uptake of existing technology & strength of industry-led control	Low due to new technologies	Low due to new technologies	High
Likelihood of exotic disease	Low in agribusinesses which use technology	Low due to education & biosecurity	Low due to import restrictions	High	Moderate- high depending on uptake of existing technology & strength of industry-led control	Low due to education & biosecurity	Low due to import restrictions	High
Consequences of disease spread (speed and scale) if new incursion occurs	High uncertainty; depends on sector; rapid high scale spread in agribusiness; hobby sector may act as bridges	High speed and scale within-herds but between-herd spread is slow if known disease	High speed and scale due to high stocking densities (and monocultures), but could be region specific	Low scale and speed - disease is rife already in a small animal population	High uncertainty; depends on sector; rapid high scale spread in agribusiness; hobby sector may act as bridges	High speed and scale within flocks but between-flock spread is slow if known disease	High speed and scale due to stocking densities, but could be region specific	Low scale and speed - disease is rife already in a small animal population
Demand	Strong (local and global)	Strong (local and global)	Moderate (local and global)	Weak (local)	Strong (Local and Global)	Strong (Local and Global)	Weak (Local)	Weak (Local)
Imports	Low	High	High imports of animal products not live animals (black markets or illegal trade)	High	High	High	Low	Low
Exports	Dependent on disease status	High	High	Low	Dependent on disease status	High	Low (UK only)	Low

In the original cattle and sheep workshops the participants created names for each scenario. These names were retrospectively considered to be value-laden so we have not used them as titles in this table. However, in order to reference these against the online report, we present the original scenario names here: C1, Status Quo; C2, In Clover; C3, Quality Street; C4, Wild West; S1, Opportunity Knocks; S2, Three Bags Full; S3, Sheepishly Smart; S4, Silence of the Lambs.

Table 4
Mechanisms to improve resilience in each scenario.

	Vulnerability	Mechanism
Professional	Fragmented industry reliant on government support	Increased solidarity within a diverse industry encompassing big and small players
	Lack of industry coordination and no succession planning	Support for a strong state veterinary infrastructure and education for new entrant farmers (focusing on biosecurity measures such as in-house diagnostics, closed herds, training risk managers)
	Black markets a concern if technological stagnation occurs through lack of research and development	Pharmaceutical legislative reform to ensure harmonised international standards for drug licensing across all markets and fast, equitable access to new drugs
Empowered	Sustainability will depend on continued incentives for technological innovation and public support	Encouraging public-private partnerships
	Lack of coordination and communication could weaken system	Streamlining efficiency through technological innovations which enable individual animal health data sharing and thus improve farmer empowerment to assess risks and prevent, detect and control animal disease
	Cattle and sheep businesses are vulnerable to novel disease incursions which could unnecessarily threaten an entire business	Compartmentalisation and regionalisation so business continues 'as usual'
Capitalist	Multi-site businesses. If culling is a disease control policy, some businesses could lose everything	Mechanisms to underwrite farmer assets
	No coordinated disease surveillance or government support	A cooperative knowledge exchange network which encompasses the supply chain network would promote strong industry links and consumer understanding of the product and the process
	Weak state veterinary service. Entire multi-site businesses may be vulnerable to strict disease control measures if disease incursion occurs.	Compartmentalisation and regionalisation so business continues 'as usual'
Opportunist	Industry-led disease control weak if no previous experience	Specialised education targeted at business farmers will ensure that the industry knowledge about disease management is relevant and evidence-based
	Animal health is a secondary priority to environment	Exploiting other government priorities (such as the environment) to incentivise positive disease risk management and good farming practices
	Low government support. High costs of treatment. Cheap meat	Increased motivation to care about disease control. Add value through other industry mechanisms
	Anyone can farm. New entrants from other sectors with variable knowledge	Farmer-led initiatives such as education
	Poor market for meat due to competition from other sectors	Premium offered on farmer-led quality-assurance schemes to identify disease-free products once they have left the farm
	Disease detection on a 'needs-must' basis	A cooperative knowledge exchange network to strengthen solidarity and coordination, communication and contingency planning within the industry
	Effective treatments of endemic diseases a challenge due to low investment in new technology and pharmaceuticals	Increased cross-sector collaboration between cattle and sheep industries will strengthen resources in disease control

disease incursion is low, because of strong government support for education and training initiatives and biosecurity measures.

3.2.1. Industry structure

Farmers focus on breeding and rearing for health in extensive production systems. Stocking rates will be high and stock may comprise monocultures. Hobby farms will exist and are not disincentivised, but will not pose the same uncertain threat as in the aforementioned 'Professional' scenario because new entrants into farming will be encouraged in the 'Empowered' future and supported by strong education and training initiatives.

3.2.2. Resilience

Government agricultural and financial support, in combination with an otherwise light-touch regulatory approach (from the EU) will result in a strong state veterinary service working in partnership with farmers to empower them to understand disease risks, improve biosecurity, and detect and treat disease rapidly. The burden of traceability and worries over cross-compliance will have been somewhat alleviated through technological improvements to electronic identification systems. These systems will have added value to existing animal health data management systems by improving data quality and detail and streamlining individual animal health data sharing across the entire food supply chain. Both cattle and sheep industries are prospering in this future; local and

global trade will be strong, helped by the eradication or improved control of many endemic diseases. Although the risk of exotic disease incursion will be low (due to new technologies and breeding for health), the high numbers of animals and greater stocking densities could lead to faster within-herd/flock transmission rates but slower between-flock rates for different diseases. Although the sheep and cattle industries will weather a disease outbreak well at a national level, perversely, individual enterprises (and specific regions) may be badly affected as the uniform and concentrated nature of the businesses may leave them susceptible to large animal losses through disease or control measures such as culling.

3.2.3. Mechanisms to improve resilience (Table 4)

Encouraging public-private partnerships will ensure sustainability of support for these livestock sectors. Streamlining efficiency through technological innovations will enable individual animal health data sharing and thus empower farmers to assess risks and prevent, detect and control animal disease. Mechanisms to enable compartmentalisation and regionalisation during a disease outbreak may offer opportunities to improve resilience. Industry-led support, through insurance schemes which could replace or augment current compensation mechanisms may also mitigate this damage. The success of the latter would rest on the nature of participation, premiums charged and the robustness of mechanisms for transparency and accountability.

3.3. Capitalist

In the 'Capitalist' future, regulation is high (at EU level), government prioritisation of the industry is low but technological innovation continues to be supported. Demand for product is moderate to weak at both local and global levels. The demand for sheep imports and exports is weaker than for cattle so competition within the industry is high. The likelihood of disease incursion is low but relatively uncertain because of low imports, trade restrictions and the potential for emerging 'black markets' for animal products.

3.3.1. Industry structure

Hobby farmers and small producers will be squeezed out of the industry through increased regulation (particularly at EU level) without the benefit of government financial support. Farming will not be seen as a profitable enterprise for entrepreneurs or new entrants; amongst traditional farmers, only the most competitive, astute producers with an eye for profit will survive. It is true that in most scenarios in the future, farmers will need to be good businessmen. However, in the capitalist future, this is emphasized more than in other scenarios because the demand for product is weak to moderate and competition is high within the farming industry. In contrast, in the 'Professional' scenario farmers are diversifying to other sources of income; in the 'Empowered' scenario all farmers are succeeding and are easily profitable; in the 'Opportunist' scenario farming is a gamble rather than a solid business venture.

Overall the industry will be small, having declined in size since 2014. Where possible and practical, intensive rearing and selective breeding for production will have been embraced. These production strategies will have resulted in high stocking densities and a shift towards monocultures. Monocultures are the result of selective breeding to create livestock populations that are adapted to specific advantages, such as feed efficiency, or resistance to a particular disease. However the associated loss of genetic diversity means these populations may be vulnerable to other disadvantages, such as new infectious diseases. The future of the industry is reliant on the success of a small number of farmers, and if livestock populations are susceptible to new and emerging diseases, morbidity and mortality rates are likely to be high.

3.3.2. Resilience

Commercial farmers will have benefited from training initiatives and will have become early adopters of new technologies. The improved knowledge about diseases and ability to diagnose and record infections will result in decreased time to disease detection and greater industry self-reliance through in-house management of disease risks. The latter will be necessary because of the weak state veterinary system. There will be fewer state veterinarians available to support day-to-day monitoring and surveillance activities for exotic diseases and in the event of an outbreak, it will be difficult to resource veterinarians for fieldwork or local and national disease control centres. Compliance with biosecurity measures will be driven by industry- and community-led incentives. There will be no government mechanisms in place to coordinate disease surveillance or control strategies or compensate for financial losses in a disease outbreak. Overall the likelihood of disease incursion will be low. However, there is a possibility that diseases which were previously under control, might re-emerge if there is a lack of expertise in animal health. The consequences would be severe if a novel disease or a new incursion of a recognised disease were to be missed. Disease will be likely to spread quickly throughout entire businesses and regions due to high stocking densities. Weaker businesses will be the first casualties of any outbreak.

3.3.3. Mechanisms to improve resilience (Table 4)

As with the 'Empowered' future, compartmentalisation could be very important for retaining business as usual in the cattle industry. Regionalisation will be likely to be more helpful to sheep farmers, particularly in heavily concentrated lowland grazing areas. Cattle and sheep farmers might look to the pig and poultry industries as leaders in this area. The resiliency of the industry will depend on the degree of professionalism of the enterprise and the ability to coordinate and communicate with other businesses. A cooperative knowledge exchange network which encompasses the supply chain network would promote strong industry links and consumer understanding of the product and the process. Specialised education targeted at business farmers will ensure that the industry knowledge about disease management is relevant and evidence-based. Exploiting other government priorities (such as the environment) to incentivise positive disease risk management and good farming practices will be likely to improve disease resilience.

3.4. Opportunist

In the 'Opportunist' scenario, the government does not prioritise the livestock sector, regulation is low and demand for product is weak at both local and global levels. Technological research and development has stagnated. The likelihood of disease incursion is high because of the depleted state of the veterinary infrastructure, lack of resources for surveillance and limited financial incentives for farmers to invest in biosecurity.

3.4.1. Industry structure

The veterinary infrastructure will be under-resourced. In a similar manner to the 'Capitalist' scenario, there will be fewer state veterinarians available to support day-to-day monitoring and surveillance activities and in the event of an outbreak, it will be difficult to resource field veterinarians or local and national disease control centres. There will be no financial rewards for those involved in livestock production to undertake further education or develop technologies to improve industry self-sufficiency. The livestock sectors will therefore be small, having declined in numbers of animals and holdings since 2014. Extensive, 'ranch-style' production systems will offer the only viable option of growing cheap meat. In the cattle industry there will be an increased demand for importation of animals and animal products which will be poorly regulated. The market for sheep meat will have been driven down by local and global demand for cheaper, lower quality meat products and exports may become non-existent.

3.4.2. Resilience

As a result of high costs of treatment, poor veterinary support and an erosion of industry knowledge and heritage, disease incursion will become a common event and endemic disease will be rife. Cattle and sheep industries will become increasingly co-dependent on each other for disease control. The frequency of disease detection will be judged on a 'needs-must' basis and as such, is only realised after significant clinical signs, mortality or loss of production has occurred. Movement restriction will be difficult to enforce and there will be no coordinated national disease control strategy. There will be challenges for disease detection as animals will not be inspected frequently and disease, if introduced, will 'rumble on'. Low investment in technology and diminishing interest in the development of new pharmaceuticals, means that effective treatment of prevalent endemic diseases will pose a major challenge to most farmers. There will also be little motivation or willingness in the industry to comply with or invest in improved biosecurity measures. Paradoxically, the lower stocking density in these extensive systems will have an unintended benefit in reducing dis-

ease transmission within and between herds/flocks, meaning the consequences of new disease incursions will be somewhat mitigated. Compensation for the cattle and sheep industries will not be possible due to the lack of government support. The absence of compensation schemes will have necessitated a 'co-existence' rather than an 'elimination' strategy for notifiable diseases and a renegotiation of relationships with current (2014) trading partners.

3.4.3. Mechanisms to improve resilience (Table 4)

In order to improve resilience, farmers will need to be motivated to care about disease control. Farmer-led education initiatives will therefore be of paramount importance in the near future. Other incentives, such as premiums offered on farmer-led quality-assurance schemes to identify disease-free products once they have left the farm are potential mechanisms to improve biosecurity and disease control. Compliance with biosecurity will be likely to improve if there is increased cross-sector collaboration between cattle and sheep industries through the development of a cooperative knowledge exchange network to strengthen coordination, communication and contingency planning within the industry.

4. Discussion: Key messages and questions for policy-makers

The EPIC scenario planning workshops have resulted in the development of four plausible but provocative views of the future resilience of the Scottish sheep and cattle industries. These scenarios highlight a number of important drivers that have the capacity to affect long-term farming resiliency such as changing industry demographics, the degree of government support and regulation, the strength of state veterinary infrastructure and the capacity for technological innovation to support the industry to meet local and global market demand. The results of the scenario planning work suggest that encouraging industry self-sufficiency is vitally important to ensure resiliency. This should be stimulated through incentives to improve in-house health management and biosecurity, education and training initiatives to promote new entrants and cross-sectoral collaboration between large and small farm businesses and public and private sectors.

The creation and subsequent discussion of non-probabilistic 'what if' learning scenarios (Böerjeson et al., 2006) during each workshop enabled participants to consider creative and novel alternative strategies for disease control which might be useful in any future. Proposed strategies focused on improving solidarity within the livestock industry through improved succession planning (via incentives for new entrants and education initiatives) and formal communication networks between farmers. Support for a strong state veterinary infrastructure and consideration of pharmaceutical legislative reform was also considered necessary to ensure harmonised international standards which enable the continuation of international trade and business as usual in the face of an exotic disease threat. As such, compartmentalisation (within businesses) and regionalisation was perceived to be an important plan for business survival. Technological innovations to streamline efficiency through better animal health data sharing were thought to improve farmer empowerment to assess risks and prevent, detect and control animal disease. Some participants were also eager to explore mechanisms to underwrite farmer assets in the event of a disease outbreak to ensure sustainability of farming in the future.

The role of subsidies in Europe, the US and Australia were mentioned as important drivers of meat and wool markets but the impacts these might have on animal demographics, animal management systems and product availability did not emerge to any

great extent in any of the scenario narratives. The likelihood and impact of changes in the level of regulation of the food production system and the interaction of such changes, with the activities of consumers, specifically their response to price setting and changes in the cost of food, were topics on which participants chose not to focus during any of the scenario planning workshops even though they are likely to have significant impacts on the relative success of businesses with different management structures (e.g. family-run versus units run with wider equity inputs). This may reflect inevitable limitations in the workshop format and the resultant data, which is naturally constrained by participant diversity, the time available for discussion, and the particularity of contextualized data elicited from discursive approaches (Wodak and Meyer, 2009).

We have examined the participant-proposed strategies for resilience in the context of the four scenarios (Table 4) and have reframed them as ten key questions for policy makers and stakeholders to provoke further discussion about improving disease preparedness across scenarios (Box 2). This continued process of dialogue at the interface between science, society and policy should have a positive impact at both the policy level where stakeholder buy-in and input are advantageous, and at the local industry level where innovation and good practice will be encouraged. This reflexive approach is not just about improving a "mechanism of anticipatory governance" (Laurie (2011) at page 351), but rather, emphasising the promotion of parallel partnerships between governance and society in the face of uncertainty, such that actors have the opportunity to contribute to and engage with a responsive government to improve the future (Laurie, 2011). In this way, we hope the results of the current study will create new opportunities to revisit discussions about the robustness and longevity of current Scottish animal disease contingency plans.

As these scenarios are possible but not necessarily probable, judgement and evaluation of them is not about revealing 'truthfulness' (Selin, 2006) but about demonstrating "trust, reliability, credibility in the absence of truth and in the face of varied influences and possible frameworks for action" (Selin, 2006). We believe that the scenarios presented in this study been useful for identifying the industry dynamics underpinning livestock disease resilience, while also helping to build credibility of EPIC research through engagement of a wide variety of relevant participant stakeholders (including decision makers), participant ownership of the process and the end scenarios, and the inclusion of credible content using a transparent and robust participatory approach (Selin, 2006).

In this process, consideration of a range of desirable and less-desirable futures has also allowed workshop participants and EPIC researchers to challenge their own commonly-held beliefs and shed light on potential blind-spots (Peterson et al., 2003) regarding animal health. These concerns or assumptions may have otherwise been previously overlooked or under-played by policy-makers or modellers. For example, compliance with biosecurity measures may vary greatly in each future depending on the level of government support, regulations and strength of industry disease management initiatives. However, in mathematical models and risk assessments underpinning current animal disease contingency plans, 100% compliance with control strategies is often assumed; it is certainly difficult to quantify and parameterise levels of compliance in a mathematical model of a possible control measure in a hypothetical future.

Although scenarios are meant to challenge and extend the margins of thinking it is important that they are still internally consistent and plausible. Some biases (such as over- or under-confidence and the tendency to look for confirmational evidence of prior beliefs) may invariably creep into scenario development unless participants are encouraged to think about the things we know we do not know and the things we do not know that we

Box 2: Key questions for policy makers and industry stakeholders.

1. Does the animal health legislative landscape provide enough flexibility and scope to adapt to new challenges presented by rapidly evolving scientific and technological developments?
2. Is there a need for veterinary pharmaceutical legislative reform to harmonise international standards for drug licensing and to expedite access to new or experimental drugs in the face of a novel disease emergency?
3. Should there be efforts to further develop and support state veterinary services and a 'veterinary reserve' through a clearer career path identified in veterinary schools?
4. How can farmers be incentivised to adopt new technologies such as individual animal health data management systems which would add value through improved streamlined data sharing across the entire food supply chain?
5. Are there sufficient upstream mechanisms to guarantee disease-free produce or would a farmer-led quality assurance mark (rather than a consumer-led mark like 'red tractor') be a useful strategy to enhance industry-led control of endemic diseases?
6. Who is best placed to provide impartial advice to farmers and lead farmer education initiatives on biosecurity and disease prevention (supermarkets, industry, government, private veterinarians)?
7. Is it necessary or desirable to have a formalised cooperative knowledge exchange network to promote solidarity and improve coordination, communication and contingency planning within the industry? Do existing organisations already fulfil this role effectively?
8. Should formal professional training programmes or continued professional development be an essential prerequisite for farming livestock in Scotland?
9. Should farming be prepared to sacrifice heritage and tradition for the sake of greater animal health security?
10. Is an industry-led insurance scheme a feasible alternative or augmentation to current valuation and compensation mechanisms during a serious epidemic?

do not know (Schoemaker, 1995). Other types of bias can ultimately be helpful. Schoemaker (1995) suggests that conjunction fallacies, (the incorrect view that the conjunction of two events is more likely than each event occurring on its own) can in fact increase the perceived plausibility of scenarios which are deemed to be highly unlikely. This may be because the conjunction of two events provides a causal explanation. For example, in the 'Opportunist' scenarios, funding and infrastructure for veterinary surveillance is drastically reduced but farmers are not investing in technologies which would improve on-farm disease control (such as electronic identification readers). One explanation may be that reduced funding for veterinary infrastructures is, through a series of intermediate steps, the reason behind technological stagnation. This causal coherence increases the perceived plausibility and possibility of the scenario even if the overall scenario itself is unlikely.

5. Conclusions

The value of scenario planning lies as much in the opportunities it creates for dialogue and information sharing as it does in the creation of the futures themselves. This exercise has enabled stakeholders to build strategic partnerships by sharing experiences, exchanging knowledge and finding common ground through understanding one another's constraints. To a certain extent the scenario planning process may therefore be considered to have facilitated an environment suitable for social learning (Reed et al.,

2010), but this cannot be identified/confirmed without further analysis, anticipated in future scenario planning processes. The solidarity created between participant stakeholders through discussion of their values and interests should be recognised as an important component of contingency planning as it is a motivating factor in the mobilisation of people into action in the face of a real emergency which poses a threat to the security of Scottish animal and/or human health.

EPIC is using these scenarios to inform ongoing work in a range of other scientific programmes. The comparison of cattle and sheep sector scenarios has identified interesting similarities with respect to important drivers, visions of the future and beliefs about vulnerabilities and strengths of the industry. Scenarios will be used to test existing and new models of disease transmission, proposed control strategies, and risk assessments which currently underpin Scotland's animal disease contingency plans. This should enhance the timely delivery of robust long-term scientific advice in the context of a rapidly evolving political and socio-economic landscape.

Conflict of interest

None of the authors of this paper have a financial or personal relationship with other people or organisations which could inappropriately influence or bias the content of the paper.

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